CHAPTER 5: Operation Part 7 Natural Gas Burners [5 of 5]

5. Personnel must be carefully instructed and trained.

Everything necessary in terms of time and investment in instruction and training (both simulated and real) is the best investment when using gas burners. Since everything seems easy at first, if there are no problems, over time carelessness develops due to a lack of training, which can lead to painful accidents.

PROBLEMS WITH DUAL-PURPOSE BURNERS (Fuel Oil and Natural Gas)

In Uruguay, the natural gas supply is generally subject to interruptions, especially when a special tariff is not paid.

This means that companies must have "dual" burners (that operate on fuel oil or other liquid fuels and on natural gas).

The problem is that when using fuels like heavy and medium fuel oil, the nozzles or openings in the gas rings (through which natural gas is supplied inside the fireplace) can become clogged (dirty with slag and fuel that obstruct the gas inlet holes), and residues of fuel oil, slag, or soot may also remain inside the fireplace.

This makes starting the fireplace with gas dangerous, so much so that without verifying that the gas inlets are free of obstructions (or that there may be ignition sources inside the fireplace that could ignite an explosive gas mixture during a delayed ignition, in addition to possible distillations of residual fuel oil that release flammable gas with the residual heat).

This obstruction of the gas inlet nozzles to the combustion chamber, when they are "blocked" or "partially blocked," will not supply gas adequately at the moment of "start-up" (when the burner is in the "start" position, after purging and returning to the "minimum start-up air" with the modulating gas valve at its minimum setting).

This causes the gas not to ignite immediately and stably, given its low pressure, due to the small flow rate of the low load or "start-up" (generally less than 25% of the maximum load and with the safety

valves opening slowly).

The gas enters an area where the pilot light cannot ignite it.

This can produce an unignited mixture inside the combustion chamber, a "lean gas" mixture (a low gas-to-air ratio), which ignites violently, causing a "combustion chamber explosion."

This situation is exacerbated if the remaining fuel oil is vaporizing combustible gases (distilling from the heat after the burner is turned off, fuel deposits that have fouled the combustion chamber and pipes), which, combined with the incoming natural gas, increases the likelihood of creating a potentially explosive mixture.

This gas mixture that hasn't ignited doesn't necessarily ignite because the combustion chamber "fills" and the pilot light ignites it. It can ignite from any heat source that is "latent" under the soot and is "rekindled" by the air purge at the start of the burner cycle. **A heat source above 600°C (1112°F) is enough to cause an explosion.**

Unfortunately, this has already happened in Uruguay, with the stokers, boiler operators, paying the price for "inexperience." They haven't received training from the burner or gas suppliers. These companies should have provided adequate training to the stokers who operate these types of burners.

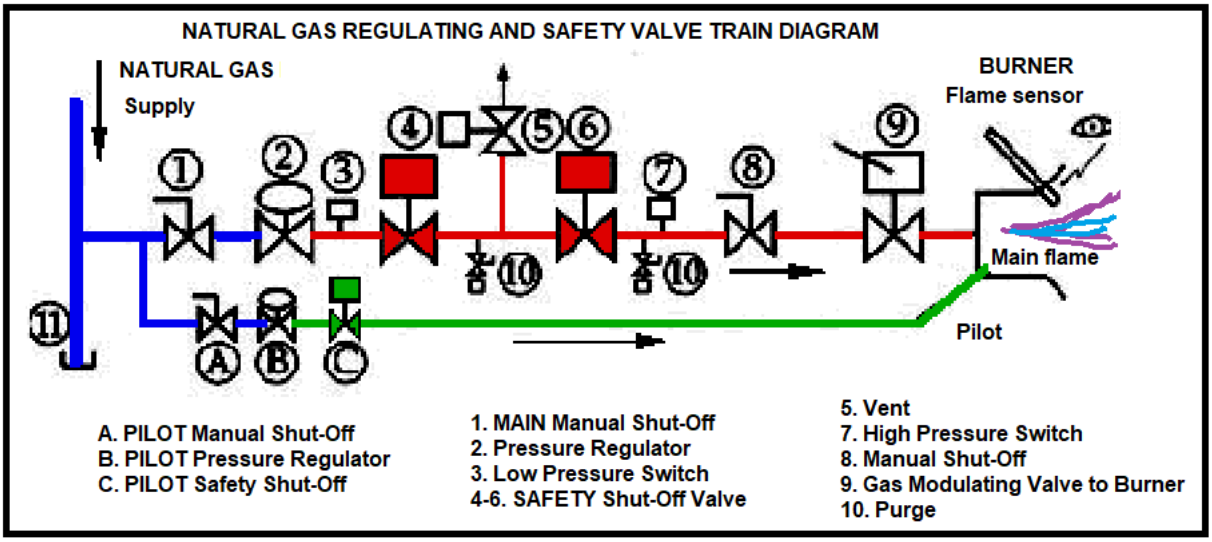
I believe it is very important that boilers that have burned fuel oil or must operate alternately with natural gas be kept clean of soot and slag deposits (I would even advise that after "brushing" the soot, before converting to gas, they be thoroughly "washed" with slightly alkaline hot water—soda—since fuel oil residue is generally acidic and causes corrosion under the conditions in which gas boilers operate: condensation occurs when the boiler is cold).

Each time gas is burned again, after a period of operation with F.Oil, perform a "large" purge (with the air intake and supply air wide open) for several minutes to ensure that the remaining liquid fuels are burned or vaporized, or that any

"hidden" combustion spots are extinguished, before switching the burner to gas operation (checking that the gas nozzles are free of slag or blocked).

The pilot flame is supposed to ignite safely after a sweep of four or more times across the entire combustion chamber and boiler tubes.

Stoker Boiler Handbook 2011, C.W.T. – CH5 Part 7 Natural Gas Burners 5 of 5



Alternatively, a 90-second sweep with the fan at no less than 60% of its full opening should be performed, and there should be no ignition source present before the pilot flame ignites. This is enabled by the "minimum air" setting for startup, allowing the main flame to ignite without being blown out.

The pilot flame may remain lit for up to approximately 10 seconds and must be detected by the photocell. A special gas sensor, usually UV-based, must not detect the electric spark that will be established a few seconds earlier.

These photocells must, in some cases, be "self-checking," and there may be more than one flame detection system in combination, such as an "ionization" rod. During this period, it is ensured that the pilot flame is correctly ignited or stabilized (for about 5 seconds, once the igniter has turned off).

Then, when the main gas supply valves are slowly opened (these are slow-opening and quick-closing), the modulating gas supply valve will already be open to less than 25% of its maximum combustion capacity (depending on the total capacity).

The main flame will have between 3 and 5 seconds to ignite with the gas pilot; otherwise (that is, after this period the pilot flame must be extinguished to ensure that the photocell only detects the main flame).

So, if the If the photocell does not detect the main flame once it has

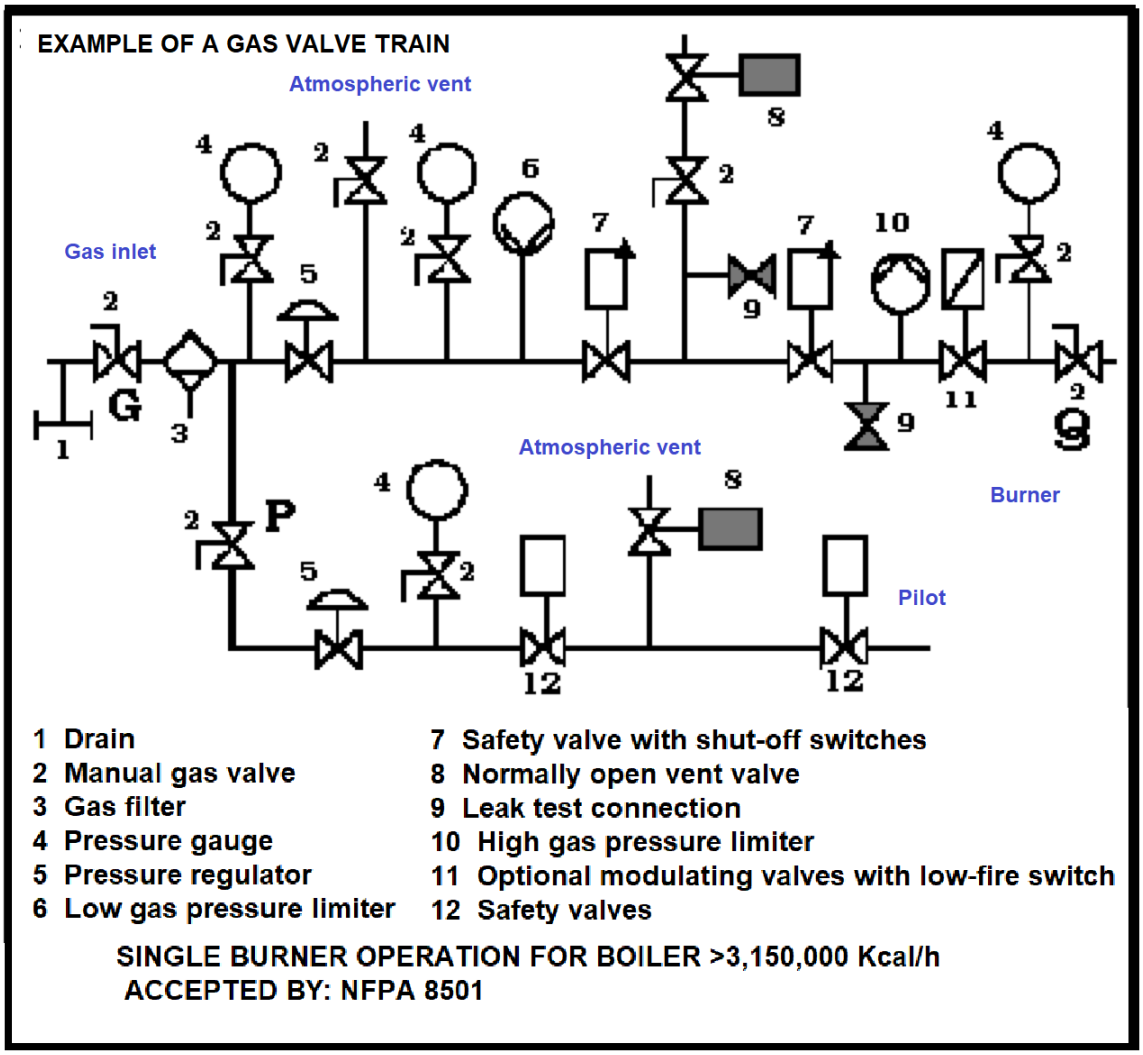
stabilized and is operating independently, it must immediately close the safety gas shutoff valves in less than one second. The main safety gas shutoff valves must close.

There are generally two valves, with a valve in the "middle" that automatically vents the gas between the two shutoff valves (in larger boilers), or a valve leak detection system. This ensures that gas cannot continue to be supplied to the burner due to a leak or failure of the shutoff valves. These latter valves are specialized and must have a mechanical indicator showing their open or closed status.

Remember that the valves supplying gas to the burner open slowly and close quickly (to prevent an abrupt gas supply and rapid closure upon detecting a fault: lack of flame, lack of combustion air, etc.).

Given the danger of switching from fuel oil to natural gas, it is advisable to check that the gas supply nozzles are in good condition. Ensure they are unobstructed and clean, or if they were protected while the burner was operating on fuel oil, check them one by one, as even those closest to the pilot light can become clogged, hindering the immediate ignition of the main flame with natural gas.

Stoker Boiler Handbook 2011, C.W.T. – CH5 Part 7 Natural Gas Burners 5 of 5



Stoker Boiler Handbook 2011, C.W.T. – CH5 Part 7 Natural Gas Burners 5 of 5

It is advisable to perform a complete burner check (or as recommended by the boiler or burner manufacturer or the relevant authority):

The following is an example of a test procedure, not necessarily the one indicated for a specific burner.

Therefore, it is advisable to follow the instructions provided by the boiler or burner vendor.

1- First, without supplying gas, by closing the gas inlet valve to the safety train (Inlet No. 2 G), the system should detect the lack of gas pressure and shut down due to low gas pressure.

Then, opening this valve and closing the other two manual valves (manual gas valves #2 at the burner inlet Q, i.e., the one closest to the boiler burner, and P, i.e., the one that supplies gas to the pilot, as indicated in the previous diagram), for both the pilot flame and the main flame,

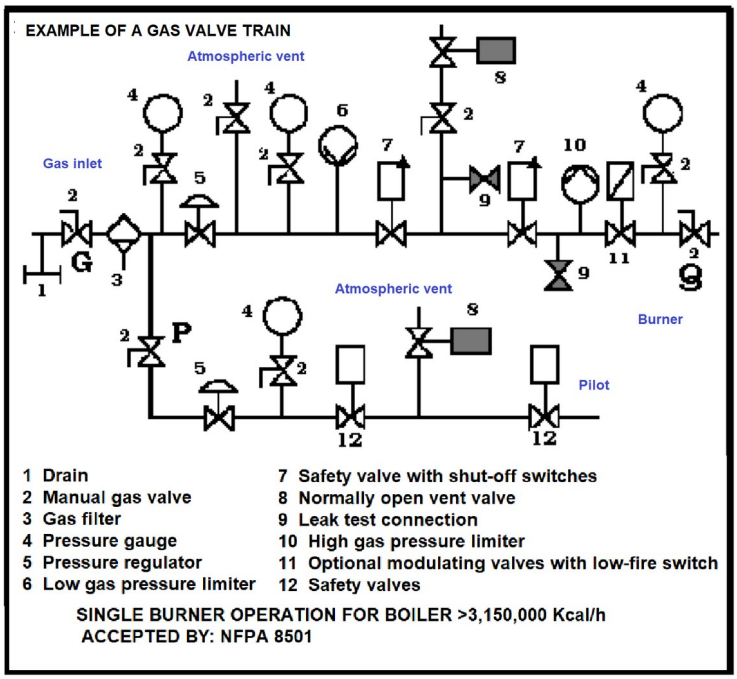
This will simulate the burner being able to ignite due to gas pressure, but not actually igniting because the gas inlets (#2, Q, and P) are closed. This will allow us to verify the timing and method of purging the combustion chamber with air, without igniting the burner (ensuring that there are four volume changes in the combustion and flue gas chambers, or 90 seconds with the air supply open at least 60%).

Verify that the burner moves down to the "minimum air for start" position, verify that the igniter produces a sufficiently powerful spark, and observe, after the pilot flame has been established, whether the operation is canceled due to "lack of flame."

During this trial period, two further tests can be performed:

Disconnecting the air pressure switch (the one that enables the system by detecting combustion air pressure) will lock the burner (the fan may not turn off, but the cycle will be interrupted, the purge will not begin, or the cycle will be suspended if the air duct connection is disconnected, locking the burner, which will then need to be replaced by the boiler operator).

Test if the burner is locked due to the presence of a flame (in this case, remove the photocell and expose it to light before the igniter starts). When the photocell detects light, the burner will lock.



2- Test again with only the pilot light enabled (by opening pilot valve #2P) after completing all the previous steps. Ensure the pilot light ignites for approximately 10 seconds (depending on the burner) and is detected by the photocell, allowing the main gas safety valves, #7, to open (these valves will function, but will be disabled by closing the manual gas inlet to the burner, valve #2Q, meaning no gas will reach the burner).

Verify that the gas pilot light ignites within a maximum of 3 to 5 seconds (the time it takes for the spark plug to ignite the gas pilot). If the gas pilot does not ignite, the flame detector will abort the operation and shut off the burner.

If the gas pilot light ignites, the programmer will let the gas pilot light run on its own for about 5 seconds, without the electric igniter, to observe the stabilization of the gas pilot flame (to see that it is lit correctly). However, if the pilot flame goes out during this stabilization time, the photocell "aborts" the operation due to "lack of flame" (the "pilot flame" has gone out and there is no main flame; the quick-closing valves, No. 7, must close in less than 1 second; the burner goes into "lockout" mode and the boiler operator must "reset" the system).

3- Only at this point should the main manual gas valve to the burner (No. 2G) be opened, thus completing the ignition process.

4- An additional test is to close manual valve No. 2Q with the burner lit and verify that the burner shuts off due to lack of flame in less than 4 seconds (the sum of the times between the flame detector registering the lack of flame, which should be less than 3 seconds and is currently less than 1 second, and the closure of the safety valves, which should be less than 1 second).

STAND SIDEWAYS IN ALL OPERATIONS, SO THAT IF THERE IS A HOME EXPLOSION, IT CAN "RIP OUT" THE BURNER OR OPEN (or "rip out") THE CLEANING "COVERS" OF THE SMOKEBOX, CAUSING IMPACT DAMAGE TO PEOPLE AND PROPERTY.

In this case, it is important to prevent these elements from impacting the gas pipes, as this would cause a fire with very serious consequences.

Although there is supposed to be protection against excess gas flow or pressure loss, which should shut off the gas, in some cases there is a quantity of gas in the pipe between the valve train and the pressure regulators and high and low pressure shut-off valves of the supply line, which are generally located away from the boiler room as required.

The safety, regulation and control valves for the gas (corresponding to the burner) should be located as close as possible to the burner (this ensures that the burner does not have to wait for the air to be "purged" from the pipe, which delays ignition and increases the risk of a bad ignition) and protected from the "impact" of a combustion explosion (placed to the side of the boiler and not facing it).

In summary (follow the instructions of the gas burner and/or boiler supplier):

Check (clean) gas supply nozzles.
Keep the boiler free of soot and slag from operation with liquid fuels (and with natural gas itself).

When switching to gas, perform a thorough purge of any remaining fuel oil, and carry out step-by-step tests on each burner stage (and

since this is not a life insurance policy, do not expose yourself to the critical area that could be affected by a combustion explosion).

Hasty maneuvers are the most dangerous; take your time!

BOILER CONVERSIONS TO BURN NATURAL GAS

One of the problems when converting a boiler to natural gas is the temperature of the metal (mandrel and/or welded) of the tubes in the first tube pass to the plate in contact with the combustion chamber, which we generally call the "hottest plate" (whether it's a dry-bottom boiler, the most problematic, or a wet-bottom boiler, a box boiler, or a semi-wet-bottom boiler with a rear tube "cap").

The metal of the plate and the "tube tips" should not exceed 425ºC (800ºF). In other words, in the "hearth tube" of fire-tube boilers, the flame must "dissipate" its heat in such a way that it reaches a temperature that does not heat the metal beyond 425ºC (with scale-laden boilers, and there are some, this can be a serious problem, since the metal does not cool properly). Otherwise, there is a risk of "burning" the metal (cracking the "tube tips", loosening the mandrels, or cracking the tubes and the plate).

This is further aggravated if the mandrel work and welding of the tubes to the plate are "poorly done" meaning that metal parts protrude into the gases (the length of the tubes outside the plate is greater than permitted; generally, it should not exceed 3 mm if they are mandrel-drilled and welded, but if they are only mandrel-drilled, it is advisable that they be "flared,"

that is, the end of the tube is "upset" with a "rounded" finish, a task that was done by hand or with a pneumatic hammer with a tip shaped like the "flap" end) or they have a poor "finishing finish" (edges, cracks, or weld "rings").

It is clear that the temperature of the gases at the end of the combustion chamber has already transferred a significant portion of the heat. In liquid fuel boilers (such as oil-fired boilers), given the high "luminosity" and short duration of the flame, approximately 40% of the heat is generally transferred. However, with natural gas, the more diffuse, less luminous flame results in less heat transfer (around 30%).

This means that boilers burning natural gas, for the same steam production "power", will have a slightly higher chimney temperature than when burning a liquid fuel such

as F. Oil (for the same "load" and excess air, i.e., the same air/fuel ratio).

Of course, the hearth must have adequate dimensions, both in diameter and length, as well as the connection of the hearth pipe to the first pipe pass (box, hood, dry bottom), for maximum combustion power.

SOOT CAUSED BY NATURAL GAS

There is an English standard that establishes a theoretical calculation formula to determine an approximate temperature of the gases at the inlet of the first tube pass (the outlet of the combustion chamber and the rear flue box between the combustion chamber and the first tube pass).

This calculation formula is based on the maximum combustion power divided by the surface area of the combustion chamber plus the corresponding bottom surface area (wet, with a hood, or without, as in the case of a "dry bottom"). This ratio is raised to a power fraction and multiplied by a factor.

If the gas temperature exceeds 800°C (1472°F), it is advisable to measure the temperature of the metal of the tubes and the back plate (it should not exceed 425°C (797°F). If it is higher, ceramic shields should be installed or the maximum combustion power reduced).

If the value is greater than 1200°C (2192°F), the maximum combustion power should be reduced below 1200°C. 2192°F. The English standard is BS 2790.

In short, when the boiler switches to burning natural gas, the maximum combustion temperature must be monitored to prevent the metal from exceeding 425°C (797°F) in that area (mandrel-bore and welded boilers can operate at a gas temperature of around 1200°C (2192°F), but mandrel-only boilers are more sensitive, so this temperature should be lower or a ceramic shield should be placed on each tube).

One way to control this maximum combustion is to monitor the flue temperature (with the boiler clean of soot and scale) to ensure it matches the value specified by the manufacturer in the design (since the temperature of the metal of the flue tube, inside the boiler, is not easy to measure and is practically impossible).

Otherwise, ceramic heat shields (tubes or nozzles) will need to be installed to protect this sensitive area from excessive heat.

This effect caused many "headaches" in countries that were converting their solid and liquid fuel boilers (since many boilers "loosened" the mandrels or cracked the "hottest" plate) **when switching to burning natural gas**, which appeared on the market after these boilers were designed for the classic fuels (the new boilers will be specially designed for gas and backup liquid fuels).

An increase in chimney temperature can indicate several things:

1- Excessive combustion, which is very risky (especially with mandrel-shaped flues).

2- A boiler clogged with soot, which poses a risk (and can lead to financial loss due to reduced efficiency), but there may also be other risks, such as an increased risk of a fireplace explosion.

Although it may seem strange, if the boiler operates with insufficient air, a poor natural gas-air mixture, or a very cold flame, natural gas can produce soot that insulates the boiler in the same way as the soot produced by liquid fuels (it is more insulating than the soot from liquid fuels due to its low density, a powder almost like "smoke black"), even though we won't see

"smoke" coming from the chimney.

The fumes are generally not soot, but rather "tiny droplets," like a "mist," of organic matter, which are present in liquid fuels and some solids. In natural gas or other gases, it can appear as "sooty smoke," which looks more like a "shadow" when held up to the light, except that the expelled gases will be somewhat more opaque when held up to the light.

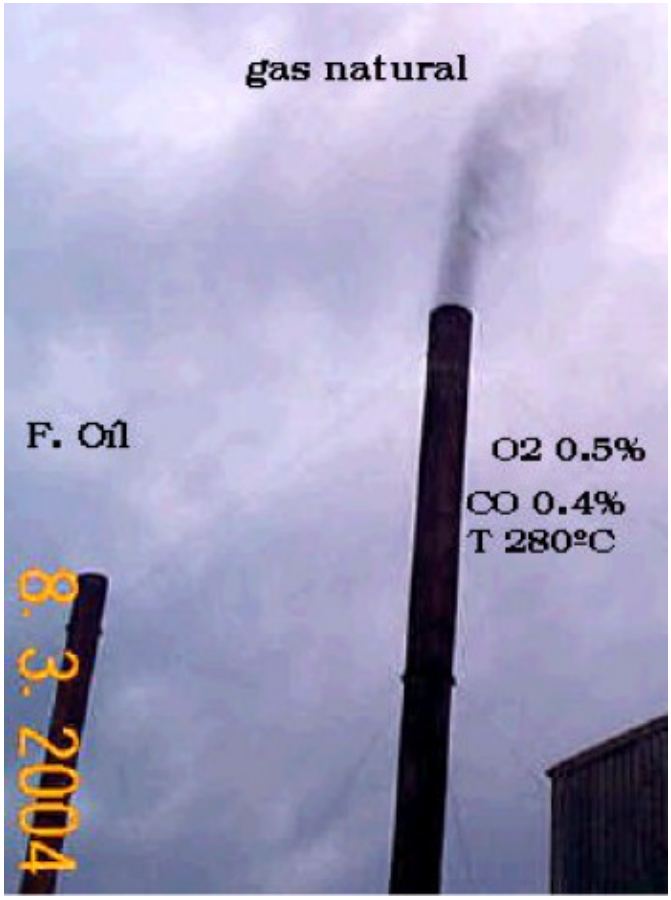
The risk may be a back-explosion, given that the gases are rich in "unburned gases" which are added to a possible "mixture" with soot dust (an extremely light soot, like "carbon black", but agglomerated in an organic form), and this mixture can ignite at any point in the boiler (including in the smoke boxes or chimney, due to a spark or combustion focus in the "soot" itself that is activated by the "sweeping" of the start-up).

3- Scaled boiler: there is a risk (danger of burning the metal due to insufficient cooling).

4- Excessive air intake: there is a risk of overheating in the mandrels (and a waste of money, as we are heating air that we don't need).

5- In some cases, combustion shift (a lack of air should lower the temperature in some cases, but in others it may be the cause of the flame shifting towards the "back" of the fire tube, or a poor air/fuel mixture, causing temperatures to rise in the area of the plate, at the entrance of the first tube pass).

Stoker Boiler Handbook 2011, C.W.T. – CH5 Part 7 Natural Gas Burners 5 of 5



In summary:

The behavior of the gas should be constantly monitored, just like any other fuel.

However, there's a tendency to think that once natural gas is burning, there's no need to clean the boiler of soot or observe the flame (since there are no visible fumes or noticeable flame colors), because with gas "nothing's wrong."

This isn't the case. With natural gas, we must be very attentive precisely because of this lack of "signals" that things are going wrong.

A change in gas pressure, or any alteration to the burner component such as a dirty turbine (the fan impeller), which must be cleaned to maintain efficiency, can cause a lack of air.

Other issues, such as dirty air controls (i.e., dirty dampers or silencers), can lead to this problem. This lack of air will allow soot to form (a fouling of the heat transfer surfaces, which will be noticeable as an increase in chimney temperature or higher gas consumption, but will not produce smoke, except for a darkening of the flue gases if the soot is expelled).

The flame will change in appearance, becoming more visible (darker and more reddish in color).

The natural gas supply pressure must be as stable as possible; otherwise, we risk the air/fuel ratio changing continuously as the pressure fluctuates. It's even possible that when gas pressure increases, there will be insufficient air, causing the burner to modulate for the same power output.

This results in both the gas and air valves closing, but since the same amount of gas is entering due to the higher pressure, less air will be available. This will cause combustion to enter an air-deprived zone, leading to the formation of CO, unburned gases, and even soot.

In short: we must remain vigilant when burning any fuel, but

especially gases, which are not very demonstrative of combustion changes (inconspicuous flame, practically no smoke formation, etc.). This also applies to cellulosic fuels (firewood, husks, etc.).